A Proposal to Test Prototype Muon Monitors for LBNE in the NuMI Alcoves

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1 Introduction

The current baseline design for the proposed Long-Baseline Neutrino Experiment (LBNE) does not include a near neutrino detector in the first phase of the project. That places a much larger burden on the simulation of the neutrino source, which will have to be supported by a number of measurements. Those measurements will include not only measurements of primary hadronic production off of the LBNE target material and materials in the horn and decay tunnel, but also measurements of tertiary muons after the absorber at the end of the decay tunnel.

The hadro-production will need to be measured at the 4–5% level in a separate experiment similar to MIPP-II [1] or NA61 [2]. While external hadron-production measurements can place strong constraints on the pion and kaon production in the target which can be compared with simulations, they do not provide any confirmation of the modeling of other key features such as the horn focusing, secondary interactions, and the pion scattering and absorption in the air-filled decay volume.

In addition to the external measurements, to verify the beam timing, beam stability, beam direction, and to confirm the simulation horn material and decay tunnel, it is desirable to constrain the flux by making independent measurements (at the 4–5% level) of the muons that penetrate the absorber. The measurements of the absolute neutrino flux using muons are also very valuable to physics measurements since they provide a constraint on the neutrino flux that is independent of the neutrino-interaction cross sections.

In this document, we will briefly describe the full-scale muon systems that are planned for LBNE. We will then propose a series of measurements that we would like to make with prototype LBNE muon monitoring devices that would be placed in the existing NuMI alcoves. The goal of the tests in the NuMI alcoves will be to provide an accurate assessment of the efficacy of the muon systems in their role in determining the LBNE neutrino flux. Their success in that role is crucial for an understanding the overall LBNE physics capabilities.

2 Proposed LBNE Muon-Measurement Facilities

The muon measurements are carried out in the region immediately following the hadron absorber at the end of the decay tunnel, below the absorber service building. An elevation view of the absorber area and the muon alcove is shown in Figure 1.

Figure 2 shows the downstream side of the absorber and a conceptual layout of the muon systems. The first set of muon-measurement devices, from left to right, is a set of three variable-pressure gas Cherenkov counters. This is followed closely by an ion-chamber array. Finally a set of stopped-muon counters which are interspersed between walls of steel "blue blocks". The blue blocks are there to provide several depths at which to monitor the stopped muons as they range out in the material. A second ion-chamber array might also be placed within the blue blocks.

Post-absorber muon measurements in most of the recent neutrino-beam experiments have typically employed a planar array of ionization counters to measure the muon profile and intensity. The NuMI [3], K2K [4] [5] and T2K [6] [7] experiments have all utilized parallel-

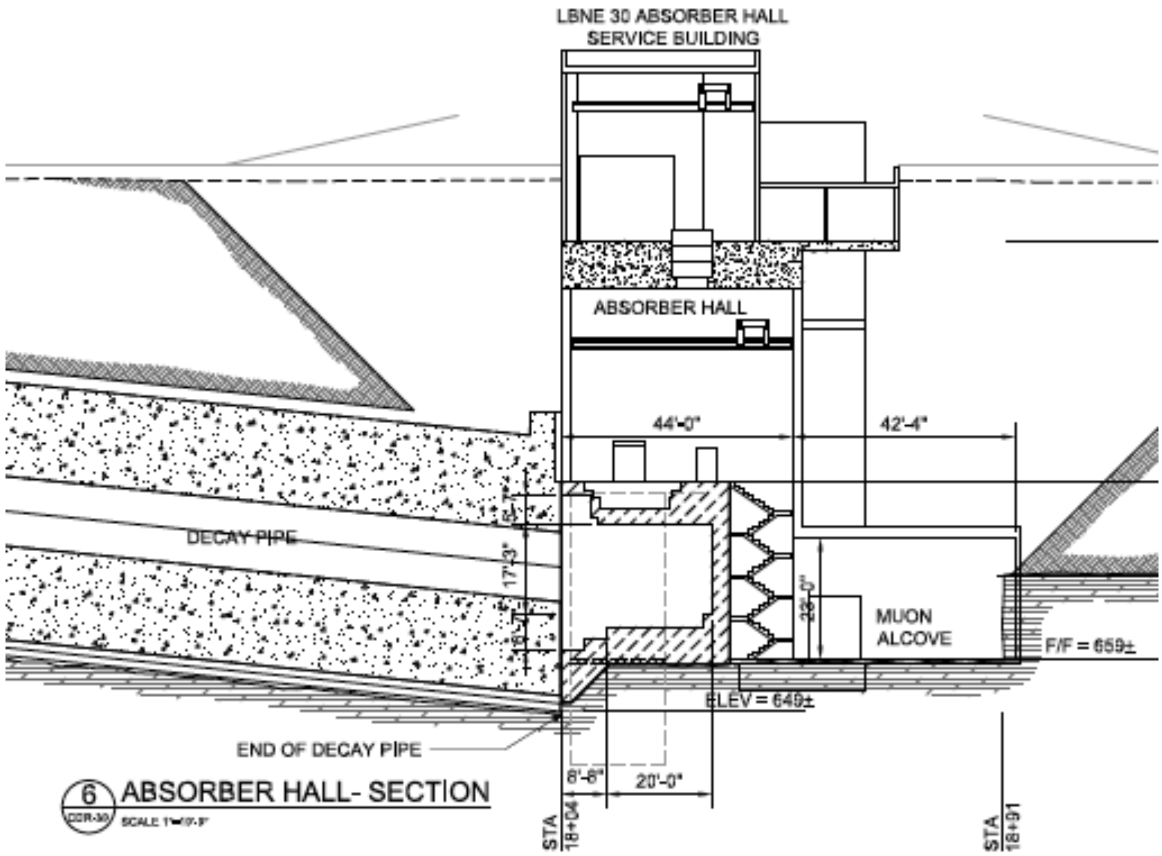

Figure 1: The absorber hall elevation view. The service building is on the surface and allows for crane access to the absorber hall. The muon alcove is directly behind the absorber.

plate ionization chambers. These counters have been shown to work in the high-radiation environment.

One disadvantage to ionization counters is that they measure the total ionization deposited from all particle species (including the delta-ray electrons produced by the muons), making it challenging to convert the ionization signal into an absolute muon flux. For LBNE we plan to use the ionization counters to monitor the beam stability, timing, direction and shape, but not to determine the absolute flux of muons or to determine the muon-energy spectrum. Instead, the stopped-muon counters (see Section 2.2) and threshold Cherenkov detector (see Section 2.3) have been proposed to determine the flux and energy spectrum of the muons.

2.1 Ionization Counters

The conceptual design for the LBNE muon-ionization chambers is similar to that used in NuMI, K2K and T2K. Due to their high radiation tolerance, sealed ionization counters are the default technology. For example, the CERN neutrino beam to Gran Sasso (CNGS)

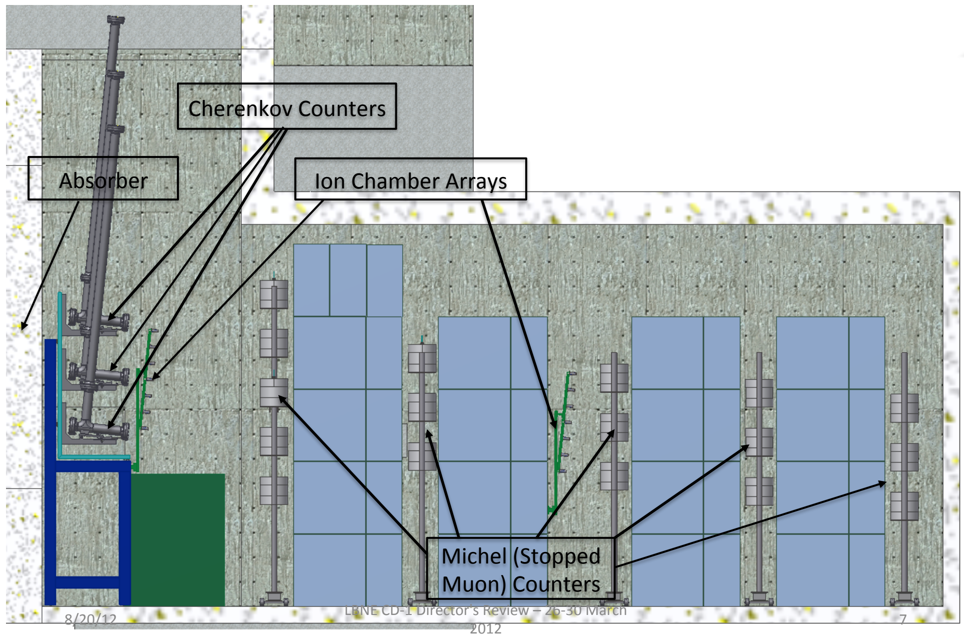

Figure 2: A layout of prototype LBNE muon systems in NuMI alcove 2.

system uses an array of Large Hadron Collider (LHC) beam-loss monitors.

Figures 3 and 4 show the conceptual design for the ion-chamber array. Our conceptual design is based on commercial ion chambers by LND Inc., model 50343. This chamber operates at 400 V and is designed to be insensitive to neutrons, which are a background to the muon signal. Twenty-five chambers will be mounted in a modified 7×7 grid pattern (really more of a "cross with corners" pattern), that is approximately two meters by two meters. Radiation-hardened cables will be used to carry the signal to waveform digitizers, providing a complete spill-by-spill record of the muon beam.

2.2 Stopped-muon Counters

An option being developed for measuring muons is stopped-muon counters. This method is still conceptual; however, in principle, it could measure the muon flux without suffering from some of the disadvantages intrinsic to systems that detect through-going muons. The strategy employed here is to stop muons in a material and look for their Michel decay electrons. The detectors will be surrounded by significant carbon content to look for μ^- capture, resulting in ^{12}B that will in turn undergo β decay. The high-carbon material, in this case graphite, surrounds a Cherenkov radiator material which is sensitive to electrons from muon decay or high-energy beta decays. In this way, the detectors can separately measure the μ^+ and μ^- components of the beam, which is especially important in anti-neutrino running. Figure 5 shows a conceptualization of a single stopped-muon counter.

Approximately nine modules would be placed at multiple depths in the shielding or rock behind the absorber in order to sample the muon flux from different energies as shown in

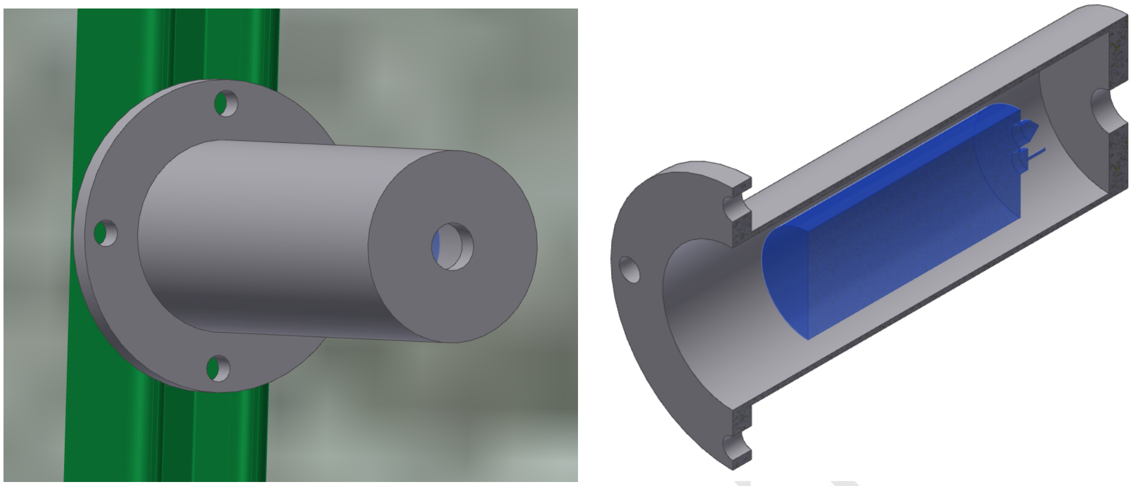

Figure 3: A model of the ion chamber housing and a section showing the commercial ion chamber inside the housing.

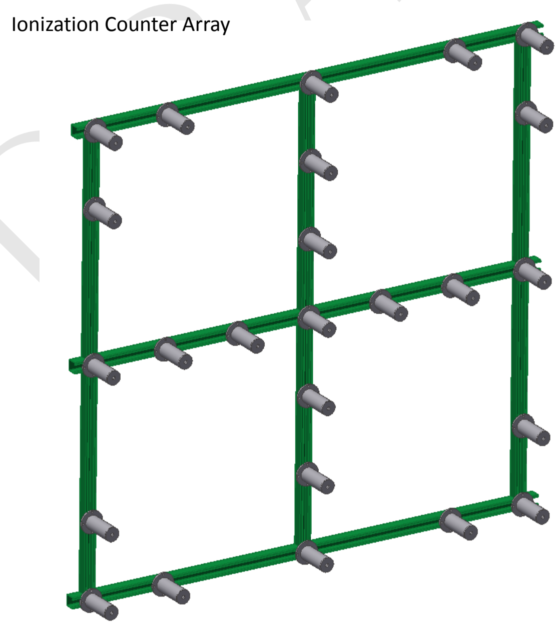

Figure 4: The proposed layout for the ionization counters. It is based on a 7x7 grid that is 1.8 m wide by 1.8 m high.

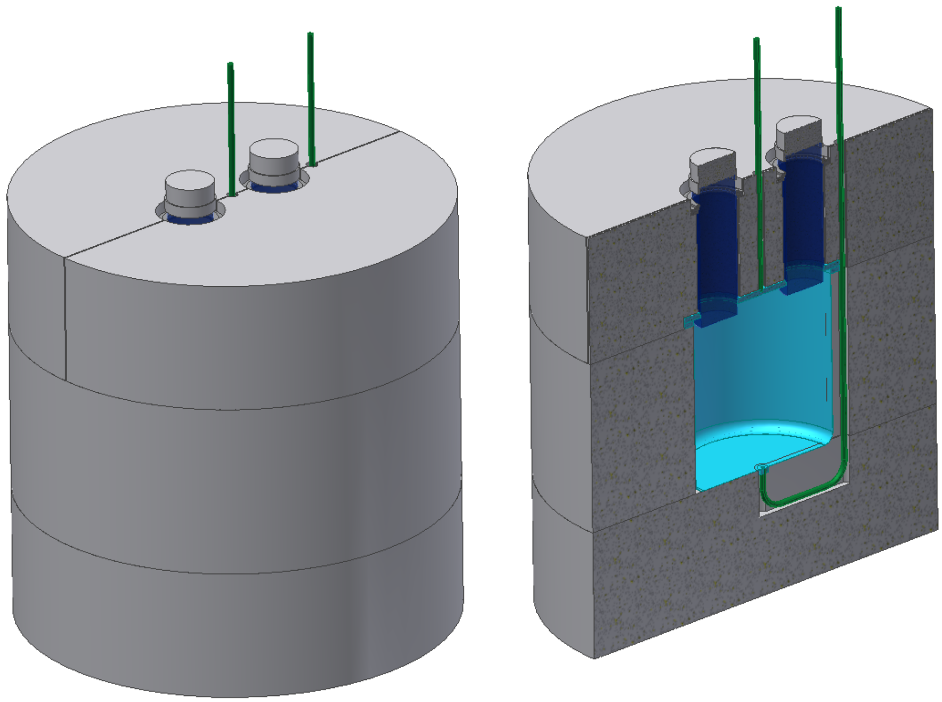

Figure 5: A conceptualization of a single Michel-electron detector (stopped-muon counter).

Figure 2. The shielding would simultaneously act to range out the muons and shield the detectors from neutrons. The Cherenkov light from Michel-decay electrons would exit of the counter and be collected by either nearby PMTs or by a light guide which would guide the light to a remote optical sensor.

The detectors would only operate in the lower-rate environment that is present many microseconds after the beam pulse is over. Long-timescale saturation from the very high-rate environment of the beam spill could affect the photon-counting devices [8]. Thus, it will likely be necessary to design fast-switching, high-voltage circuits that turn on the photon counters in the first few microseconds after the spill is over. A similar system was developed in the 1990s for the Brookhaven Muon (g-2) Experiment [9] .

Although this technique has never been tried on a large scale, a small demonstration project in K2K was able to see Michel decays with a 10^3 signal/background ratio and to measure the absolute rate with 30% precision[10].

2.3 Threshold Cherenkov System

As mentioned above, one disadvantage of an ionization system for the muon monitors is that it measures the ionization due to all particles, including delta-ray electrons and neutrons. This makes it difficult to determine the muon flux. Furthermore, the ionization system is unable to measure the momentum distribution of the muons. To resolve this problem, T2K

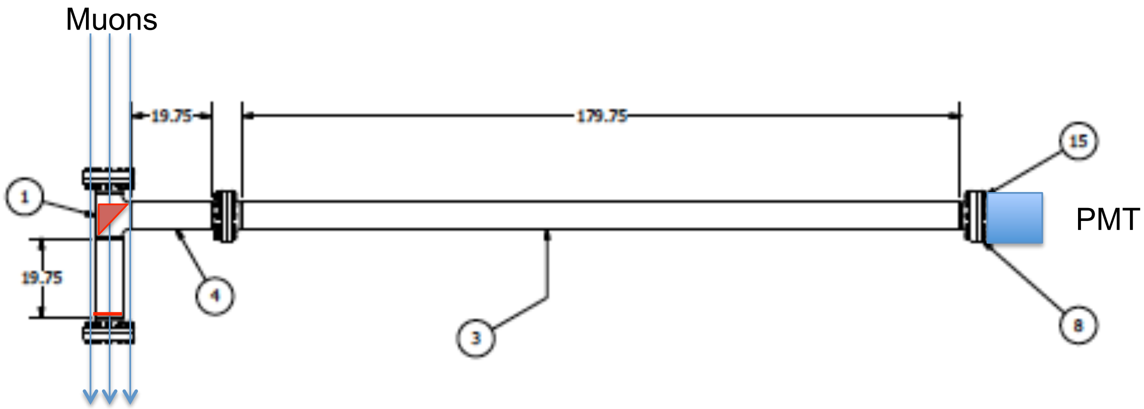

Figure 6: The Cherenkov counter conceptual design. Muons at threshold momentum emit forward Cherenkov light which is reflected via two flat mirrors to a PMT located outside of the muon radiation field.

is considering the idea of deploying a Cherenkov counter downstream of the absorber. If deployed by LBNE, a Cherenkov counter would not image individual Cherenkov rings, but rather would see the integrated signal from many muons due to the very large instantaneous flux. In addition, by varying the radiator gas pressure, and hence the Cherenkov threshold, the system's index of refraction would vary, allowing it to map out the muon momentum distribution.

The conceptual design for the threshold Cherenkov devices consists of a gas radiator is contained in a pressurized tube. The Cherenkov light in a narrow cone is collected at the end of the tube by a mirror that reflects the light 90 degrees towards a photosensor located outside the high-radiation field of the alcove. The gas pressure, varied from vacuum to several atmospheres, would determine the index of refraction, and hence the muon-momentum threshold. Several such tubes could be constructed in an array transverse to the beam direction. The resulting pressure scan would give the momentum distribution of the muons at an array of points across the end of the absorber.

Figure 6 shows conceptually how the Cherenkov system might be constructed. Safety considerations suggest that the diameter of the radiator tube and light-guide tube be six inches or less. The use of a noble gas, e.g., argon, as the Cherenkov radiator would enhance the radiation hardness of the system. A photosensor, located outside the direct radiation field of the muons, would view the primary mirror through a telescopic optical system focused on the mirror.

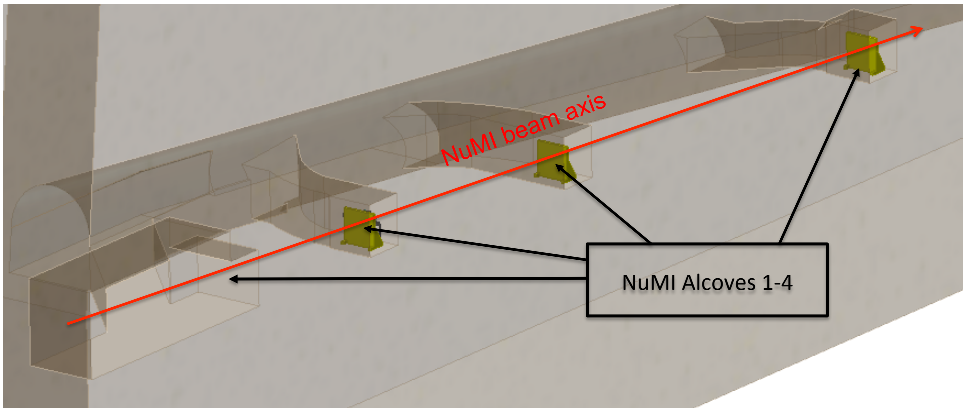

Figure 7: A model of the NuMI alcoves, numbered 1 to 4 from left to right. Alcove 2 is where the proposed LBNE prototypes would be located.

3 Prototype Plans in the NuMI Alcoves

3.1 The NuMI Alcoves

The NuMI alcoves, depicted in figure 7 provide an ideal place to test prototype modules of the LBNE muon systems, because the muon beam intensity is close to that expected at LBNE. With the Fermilab accelerator complex shut down until March, 2013 for the Nova upgrade, there is a unique opportunity to install the services for prototype LBNE muon system detectors, and possibly install the prototypes themselves.

Figures 8, 9, 10, and 11 show pictures and a conceptual model of NuMI alcove 2. We are working with Fermilab personnel to define the requirements for such an intallation, including safety and services.

After the shutdown ends, it will become much more difficult or impossible to perform significant work on infrastructure in the alcoves due to the high radiation levels when the beam is on. There will likely be short accesses which would allow for occasional, well-organized installation of instrumentation.

Our proposal is to install the infrastructure necessary to test LBNE muon system prototypes prior to NuMI startup in March, 2013. This would include any cables, racks, power, ACNET, gas, and water services required by the three prototypes. In addition, it is likely that some of the prototypes may be ready before the shutdown ends and could also be installed at that time.

3.2 Ionization Counter Prototype

3.2.1 Description

For the ionization counters, we propose to deploy a small array of 5 ionization counters in one of the NuMI alcoves. Again our proposed design is to purchase several commercial devices

Figure 8: A photograph of the second alcove in the NuMI muon beam.The main muon chambers are mounted to an aluminum frame. LBNE prototype muon chambers would be inserted behind the chambers.

such as the LND, Inc. model 50343. These would be attached to a simple unistrut frame in a "plus" pattern. Ideally these should go in the first or second alcove if space permits.

These counters would require a high voltage power supply and a digital oscilloscope for the readout. As they are sealed devices, they will not require a gas handling system.

3.2.2 Goals of Ion Chamber Tests in the NuMI Alcoves

The goals of these prototype tests are to determine the stability, reliability, and long term response to radiation exposure of these devices. Initially the goals of the prototyping tests would be to verify that the response is correlated with variations in the beam intensity, and to monitor the stability of this response with respect to environmental conditions such as the alcove temperature and air pressure. Ideally they would be deployed for several years to ensure that the output per proton on target is stable over long time periods and that the damage due to radiation exposure is understood.

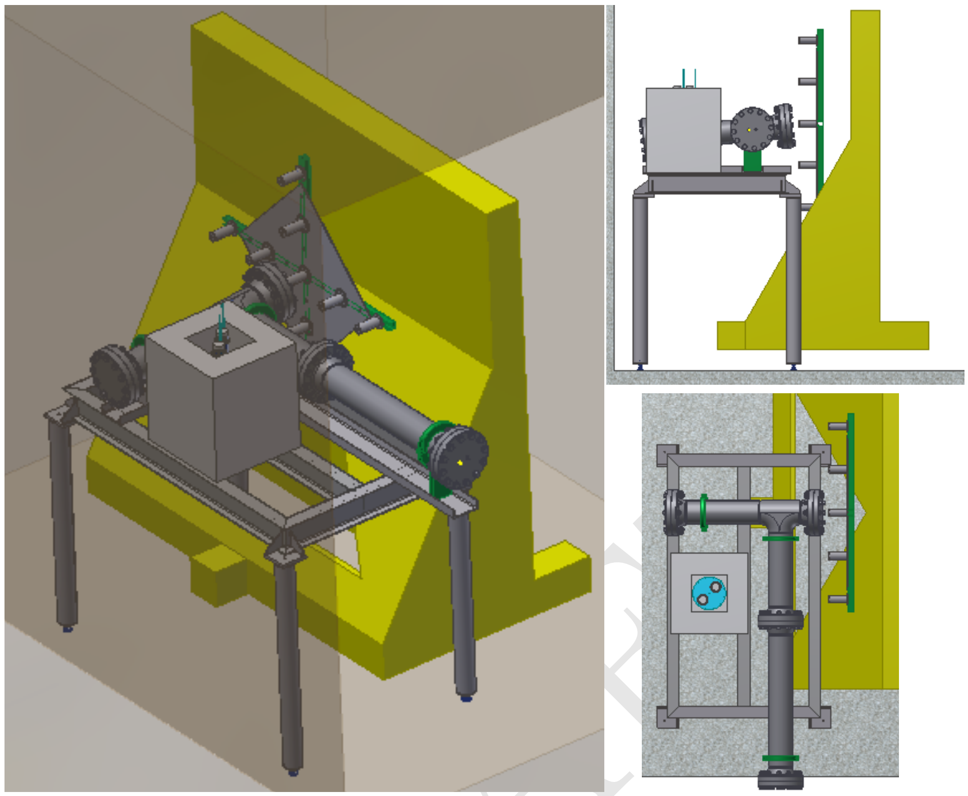

Figure 9: A conceptual model of how the muon system prototypes might be positioned in NuMI alcove 2.

Figure 10: Photographs of the cable tray providing services to the second alcove in the NuMI muon beam.

Figure 11: Photographs of the rack area next to the second alcove in the NuMI muon beam.

3.3 Stopped Muon Counter Prototype

3.3.1 Description

The prototype stopped muon counters would consists of 2 or 3 modules, ideally placed in different alcoves to be able to obtain some information about the muon energy spectrum. The water would be housed in a stainless steel can surrounded by graphite slabs. The water would be circulated. Each can would house 2 PMTs, connected to a HV supply that would be gated off during the main part of the proton beam spill, and would be turned on after the pulse to look for the delayed muon decay signature.

3.3.2 Goals of the Stopped Muon Counter Tests in the NuMI Alcoves

The initial goal of the prototype test would be to test the PMT HV gating circuit and to look for a clear muon decay signal (with the appropriate lifetime) in the data following the beam pulse and to determine the background rates that could be present (due to sources such as slow neutrons) that could limit the signal sensitivity of the devices. It would also be important to study the rates of observed stopped muons to determine how well they agree with predictions and with the measure muon fluxes determined by other devices such as the ionization counters and the existing NuMI muon monitor measurements.

The radiation environment will be with these initial prototype detectors in the NuMI muon alcoves. Studies will be performed to determine if the photon sensors can survive the radiation environment at the location of the Michel detector. If the sensors can survive, they can be attached directly to the Cherenkov medium; if not, optical guides will have to bring the light to a lower-radiation area to the side of the beam. Potential radiation damage to the Cherenkov radiator itself will also be studied.

3.4 Threshold Cherenkov Prototype

3.4.1 Description

The Cherenkov prototype would be a gas filled L-shaped pipe with a mirror at 45° degrees to the beam axis to reflect the light to a lower radiation area. Since the NuMI beam is not as broad as the planned LBNE beam with its larger radius decay volume, the long arm of the L would likely be somewhat reduced in size to fit inside the alcove. It would lie horizontally in the alcove and could be supported by a table or a simple frame. The prototype would be filled with Argon or Nitrogen gas and would require a gas handling system to be able to vary the gas density. Due to the large muon flux, the expected light level is high and the devices could be read out with APDs or photodiodes rather than PMTs.

The Cherenkov counter would be constructed and tested for integrity in a surface lab at the University of Colorado, Fermilab, or Los Alamos. After a safety review, the prototype counter would be device placed NuMI alcove 2.

3.4.2 Goals of Cherenkov Counter Tests in the NuMI Alcoves

Because this type of system has not previously been deployed for a muon monitor, significant design work and testing will be required. It will be important to understand the noise and background light from non-Cherenkov sources, such as fluorescence and scintillation in the gas and transition radiation. Some of this testing could be done with cosmic rays. But a small prototype system in the NuMI beam alcoves would be very useful for confirming the expected signal intensity, determining the long term stability of the signal, the radiation tolerance of the photosensors, and to look for potential non-Cherenkov backgrounds.

3.5 Service Requirements for LBNE Prototypes in the NuMI Alcoves

The initial plan for services is to put as much external equipment as possible at the downstream end of the alcove tunnel, close to the elevator, referred to below as the "downstream location". That is a distance of nearly 200 meters from alcove 2. This could include data aquisition, gas bottles, and gas pressure controls. However, some equipment will be needed directly outside of alcove 2. Thermocouples will be needed to measure temperatures on the detectors themselves and the readout should be nearby.

3.5.1 Service Requirements

Here we list services which require work in the tunnel next to the muon alcoves. We feel that they should be installed prior to the beam start-up in March, since the tunnel becomes a radiation area after beam start-up.

- An electronics rack in the hall outside of alcove 2 with at least one 20A 120V circuit would be required for high voltage. Power for a vacuum pump to evacuate the Cherenkov counter.

- Two racks with power at downstream location near the elevator
- Install a cable tray from the alcove 2 racks to the downstream location. The cable tray would carry timing and detector signals from alcove 2 to the downstream location. The cable tray installation can also support the gas tubing connecting gas bottles with pressure controller.
- Cherenkov counter services:
  - signal and HV cable for PMT
  - Temperature and gas pressure sensor readout (ACNET?)
  - Gas fitting connected to length of tubing connecting to gas controller located in rack outside of alcove 2
  - Gas controller has ability to vent gas through a tube to an acceptable location
  - Remote controlled valves to pump out or pressurize the Cherenkov counter
  - Locate the gas bottles at the downstream location that we can access when the beam is on. Alysia is worried about the long distance to the elevator (600ft/180m). A closer location would be nice but not a show stopper. 50 lengths of copper tube go for $250 each. Alysia is also worried about leaks but with careful installation we can solve that problem. We need to discuss with Mike if a location up the ramp is possible.
  - HV located in rack, we need Ethernet interface
  - Need angle adjustment hydraulic control of wedges to change angle of the T allowing us to scan the beam to get the correct angle.
- Ionization counter services:
  - signal and HV cables for chambers
  - Temperature sensor readout (ACNET?)
  - HV located in rack with ethernet interface
  - We will have 9 detectors but maybe only 1 or 2 readout by a scope. Need to install cables from racks to downstream scope location.
  - Readout remaining detectors with integrating ADCs? Located in VME crate that we borrow from controls group?
- Stopped muon counter services:
  - signal and HV cable for PMTs
  - Temperature and water level sensor readout (ACNET?)
  - Water maintenance during shutdowns using 5 gallon water bottles for fill and drain. Access to air pressure to help with fill and drain (small air pump?)

– HV supply located in rack near alcove 2. Need to gate PMTs using special switching bases?
– Ethernet service to alcove 2 and location where we set up scopes
– Timing signals to downstream scope location. Assume that acnet services available in racks located between alcove 1&2.

4 Prototyping Schedule

Figures 12, 13, 14, and 15 show the preliminary task lists for the three prototypes and preliminary estimates of labor and M&S costs. We expect a number of the M&S costs to decrease as we evaluate existing electronics as a substitute for new purchases. We expect more refined estimates as we develop a resource loaded schedule based on those task lists.

4.1 Design and Construction Schedule

Designs for the three prototype systems are in progress. We expect that we will have final designs for the three prototype systems this fall allowing us to place orders for components. Construction will take place as components arrive. Optimistically, some of the prototypes will be ready by end of January and can be shipped to Fermilab for installation.

We are working with Fermilab to determine how to optimally place electronics so that access to them is possible during NuMI 700kW operations. This includes any ACNET, internet, power, gas, and water requirements for the systems. We are working with Fermilab to determine our needs for services such as cable trays, racks, ACNET, and power. We plan to have those needs determined over the next several months so that installation could take place prior to NuMI start-up.

4.2 Installation Schedule

The general schedule would have services installed prior to the NuMI FY13 start-up, along with the ion chamber array prototype. We hope to have the Chereknov counter and Stopped Muon counters ready by then also, but there are some lead times on components that are unknown at the moment. Installation of the prototypes after the start-up will be more challenging since we would have to wait for a short NuMI shutdown to have access to the alcoves.

4.3 Operation Schedule

Once installation has been completed for the individual systems we would bring them online individually and iterate through cycles of measurement, performance evaluation, and design refinement until we reach system designs that meets LBNE requirements. That process would take place during FY13 and part of FY14.

If such a schedule can be achieved, vital input to the physics capability of LBNE for the CD-2 and CD-3 risk assessment would be possible.

Cherenkov Counter Prototype	Construct Tee, allow additional time for design decisions on mirror flanges, extension and PMT			make 2 assemblies	The end flanges and extension are decoupled from the Tee. Initially use blanks. Test fixture needed for modified blank flanges and extension.
Decide counter configuration and performance specifications		FY12		Jan, Alysia, Geoff, John (8 h)	Decide on geometry for counter, pipe diameter, gas pressure range, optical sensor(s?)...
Initial meeting with LANL safety		FY12		John (16h), Jan (8h)	Review basic plans for pressure saftey considerations
Touch base with FNAL Safety		FY12		John (4h), Jan (8h)	Review basic plans for pressure saftey considerations
Bless commercial components		FY12		John (8h), Jan (8h)	Review basic plans for pressure saftey considerations: mechanical parts for major pipe sections, flanges, and rad-hard gaskets
Order Tee Components and end flange blanks		FY12	$10K	John or Walt	Order mechanical parts for major pipe sections, flanges, and rad-hard gaskets
Design and order light baffle and black inner-surface coating of SS pipes		FY12	$5k WAG	Jan, Alysia, Geoff, John (20 h)	Optically absorbing baffles and inner coating to minimize stray light
Identify welding vendor		FY12		John (8h)	
Vendor welds components		FY12-13	$10K WAG		Weld pipe sections and flanges
Install light baffle and black inner-surface coating of SS pipes		FY13		LANL Tech (20 h)	Install light baffles and apply black inner-surface coating of SS pipes, may require heating for full curing of material
Assemble and perform safety test at LANL		FY13		John (8h), LANL tech (80h)	Assemble pipe and flange blanks and validate integrity under pressure and vacuum
Design blank end flange test fixture		FY12-13		Jan (40h)	Design flange for optical sensor readout. This will have feed-throughs which alough HV and signal cables from the internally mounted PMT
Decide on and order mirrors		FY12	$10k	Jan, Alysia, Geoff, John (8 h)	Decide on mirror type, size, and vendor
Design and order mirror flange parts		FY12	$5k WAG	Jan/Geoff/Alysia/John (40h)	Mirror flanges designed to include adjustment screws for mirror alignment and rad-hard gas pressure seals
Design PMT Base		FY12		Jackie/Geoff (40 h)	Design PMT base for radiation environment and switched voltage operation
order light sensor(s)		FY12	$10K WAG	John or Walt	Place orders for optical sensors with chosen vendor.
Purchase PMT Bases		FY13	$2k WAG	Jackie (20 h)	order PC boardsand components
Assemble and test PMT Bases		FY13		Jackie (20 h)	
Design gas system		FY12		Jan (80h), Geoff (8h)	Design gas system which must be operable from vacuum (10^3 torr) to 20 atm, remote operation would be preferable but not essential. SS components only. Critical parameter is gas density (P/T)
Order gas system components		FY12-13	$20K WAG	John or Walt	Place orders for gas system components with chosen vendor.
Construct and test gas system		FY13		LANL tech/John (100 h)	Test gas density (pressure and temperature) control and monitoring
Module assembly		FY13		CU/LANL Techs (80 h)	
Design cable and gas pipe plant		FY13		FNAL Techs/Eng (40 h), CU/LANL Techs (40 h)	Design HV/Signal/T sensor cabling and gas supply and return piping
Plan infrastructure for MINOS alcove test		FY12-13	$10K WAG	FNAL Eng./Jan (120h), Geoff	Assume alcove 2. Need to document existing installation and plan new installation
Detector checkout		FY13		LANL/CUTechs (40 h), UP/PD/Student (160 h)	

Figure 12: The task list for the prototyping of the Muon Cherenkov Counter.

Stopped Muon Counter Prototype	can (8 liter) with fill and drain. Carbon slabs to mock up final detector			make 2 assemblies	Likely CU activity because studies can be done with cosmic rays at CU
Decide system configuration and performance specifications		FY12		Jan, Alysia, Geoff, John (8 h)	Decide on module geometry and performance specifications
Decide volume and PMT issues		FY12		Geoff(8h), Alysia and Eric	current assumption: 8" dia can, 8" high w/ 2ea 2" diam PMTs, Design PMT mounting, light collection, direct mount versus light pipe.
Create drawing package for module assembly		FY12		Jan (40 h)	Create drawings for metal can, graphite material, PMT mounts, water circulation, fiber optic connector for laser pulser
Order module assembly parts		FY12	$5K WAG	Walt or John (20 h)	Order components for assembly including PMTs
Identify commercial graphite slab components		FY12		Jan (8h), Geoff, Eric, Alysia	
Order graphite slabs		FY13	$7K x 3 ($30K) WAG	this cost should increase because some blocks non standard - $20K WAG	6" thick graphite box weighs 600lbs
Design water circulation system		FY12-13		Jan (120 h)	safety issue - rules wrt tritium in water and how this issue drives the design. Rules for MINOS test may be relaxed
Water circulation design review		FY13		Jan (8h), Geoff (8h), John (8h), Walt (8h)	
Design PMT Base		FY12		Jackie/Geoff (40 h)	Design PMT base for radiation environment and switched voltage operation
PMT base review		FY13		Jackie (8h), Geoff (8h)	
Design HV gate circuitry and identify power supply		FY12-13		Hans (80 h), Jackie (200 h) WAG, Geoff (16h), Jan (16h)	The gate circuitry likely needs to be close (50ft?) to the light sensors
HV gate circuit review		FY13		Jan (8h), Geoff (8h), Jackie (16h), Hans (8h)	
Purchase PMT Bases		FY13	$5k (8 bases)	Jackie (20 h)	order PC boards
Assemble and test PMT Bases		FY13		Jackie (20 h)	Mount components and check connections
Purchase HV gate prototype		FY13	$5k	Jackie (8h)	Purchase switched power for PMT bases. This lowers the voltage during the proton spill and raises it again directly after the spill.
Purchase HV power supply		FY13	$3k		
Troubleshoot HV gate prototype		FY13		Jackie (160h), Geoff (16h)	
Design Review of stopped muon counter		FY13		Jan (8h), Geoff (8h), Alysia	
Purchase water circulation components		FY13	$20K WAG		
Assemble water circulation system		FY13		CU tech (80h)	
Test water circulation system		FY13		CU tech (80h)	
Module assembly and test		FY13		CU/LANL Techs (80 h)	Assemble PMT, metal can, graphite, water, signal, electrical, optical components
Design cable and water pipe plant		FY13		FNAL Techs/Eng (40 h), CU/LANL Techs (40 h)	
Detector checkout		FY13		LANL/CUTechs (40 h),UP/PD/Student (160 h)	

Figure 13: The task list for the prototyping of the Stopped Muon Counter.

Ionization Counter Array Prototype	9 detector cross				CU availability low for rest of CY 2012 should be LANL activity
Decide system configuration and performance specifications		FY12		Jan, Alysia, Geoff, John (8 h)	Decide on geometry chamber array,cable type, and performance specifications
Purchase 10 counters		FY12	$4K		120 day delivery
Design chamber enclosure		FY12		LANL/CU Techs (20 h)	
Purchase chamber enclosure parts		FY13	$2K WAG	LANL/CU Techs (20 h)	
Assemble chamber modules		FY13		LANL/CU Techs (20 h)	
Identify suitable power supply		FY12		Hans (2h), Jan (8h), Jackie (8), Geoff (8)	500V, 10ma with slow control interface shared by counters
purchase power supply		FY12	$2K WAG		
design unistrut stand for 9 detector cross		FY12		Jan (16 hrs)	
order unistrut components		FY13	$1K WAG		
construct unistrut stand		FY13		LANL tech (16h)	
Troubleshoot cross at LANL		FY13		Jackie (40h), Geoff (40h)	Need some DAQ components
Test at LANL		FY13		Geoff (40h)	
Plan infrastructure for MINOS alcove test		FY12-13		FNAL Eng./Jan (120h), Geoff	Assume alcove 2 or 3. Need to document existing installation and plan new installation
Module assembly		FY13		CU/LANL Techs (80 h)	
Design cable and gas pipe plant		FY13		FNAL Techs/Eng (40 h), CU/LANL Techs (40 h)	
Detector checkout		FY13		LANL/CUTechs (40 h), UP/PD/Student (160 h)	

Figure 14: The task list for the prototyping of the Ion Chamber Array.

Review needs and identify suitable electronics that can be used for testing and for final config	FY12		Hans (40h), Jan (40h), Jackie (40h), Chuck Lane	The CAEN modules appear to be too expensive for pre CD2 activities. Check what's available at FNAL and check whether FNAL beams division has suitable systems already integrated with ACNET
purchase electronics and DAQ components	FY13	$50k (FNAL provides VME crate)	Jackie, FNAL eng.	Order electronic components for trigger signals, readout, any computers needed for data acquisition, and network infrastructure
Travel	FY12-12	$20k		
Preparation of Fermilab Alcoves	FY13	$20K WAG	FNAL Techs, M. Andrews (160 h), LANL/CU techs (80 h)	Prepare services in alcove areas for muon systems including racks, power, cables, gas and water pipes, network, trigger signals, and any ACNET related DAQ.
Installation of detectors in alcoves	FY13		LANL/CU techs (160 h)	Installation of three muon detector system prototypes in alcoves
Detector checkout	FY13		LANL/CUTechs (40 h), UP/PD/Student (160 h)	Full systems check out for all prototype modules, DAQ

Figure 15: The task list for the electronics and Fermilab effort.

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